Real-Time Wireless Decision Support Alerts on a Palmtop PDA

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The authors devised a system which continuously analyzes data exported from a Clinical Information System for the occurrence of exceptional or life-threatening clinical events. A configurable rule-based system was created to detect and act on such events. When detected, the system formats an alerting message, dials a modem and transmits the message to a commercial satellite relay system. Ennunciated by an alerting beep and blinking LED on a PCMCIA receiver card, the alert message appears on the screen of a Palmtop Personal Digital Assistants (PDA) carried by designated clinicians.

INTRODUCTION

Computerized clinical information systems (CIS) provide a means of automatically collecting and recording clinical data from a variety of sources. A well connected CIS may receive data from laboratory systems, blood gas systems, bedside physiologic monitors, ventilators, urimeters and other systems.[1] This data may be displayed at the bedside or remotely and may be printed or electronically archived for the permanent medical record.

A secondary use of the data is for generating clinical alerts. Shabot and others have described a method of automatically extracting data from computerized charts for the purpose of scoring severity of illness, intensity of interventions and for prediction of impending adverse clinical events.[2,3] Automated clinical alerting for laboratory results has been described by Bradshaw and Shabot.[4-6] This report describes the extension of the extraction and alerting process to real-time wireless notification of care providers using a Palmtop PDA.

METHODS

A HP CareVue 9000 CIS (Hewlett-Packard Co., Clinical Information Systems, Andover, MA) was used in a 20 bed Surgical ICU. The CareVue system is connected to clinical laboratory and blood gas computer systems over HL7 data links. Bedside data is provided over data links to physiologic monitors, ventilators and electronic urimeters.

The authors wrote a software package in C++ which monitors for exceptional or life threatening events in two major ways. First, the incoming data stream from the laboratory and blood gas computer systems is programatically monitored for the presence the HL7 critical value flag. When present, the wireless alerting system is activated. Second, all CareVue data is periodically and automatically exported to a secondary database located on a separate (non-CareVue) server system. Using a configurable rule-based table of "exception conditions", the authors' software combs each patient's data for the presence of such a condition. Algorithms for exception conditions currently include:

- *FiO2 > 60% for > 4 hours*
- *PEEP > 15 cm H_20*
- *Systolic BP < 80 mm Hg and no pulmonary artery catheter*
- *Systolic BP < 80 mm Hg and pulmonary wedge pressure < 10 mm Hg*
- *Pulmonary wedge pressure > 22 mm Hg*
- *Urine output < 0.3 cc/kg/hr and not admitted in chronic renal failure*
- *Ventricular tachycardia*
- *Code Blue*
- *Re-admission to ICU < 48 hours post discharge*

0195-4210/95/$5.00

When a laboratory alert or exception condition is detected, the software package formats a message using the Motorola TAP protocol, then transmits it via modem to a nationwide commercial message relaying system (HP StarLink, Hewlett-Packard Co., Corvallis, OR). Using a Personal Identification Number (PIN), the message is then transmitted to a StarLink PCMCIA receiver card inserted in a Palmtop PDA (HP 200LX PDA, Hewlett-Packard Co., Corvallis, OR) carried by an on-call ICU physician. StarLink software transfers the message to the ODA screen. A diagram of the system is shown in Figure 1.

RESULTS

Execution of the algorithm to transmit critically abnormal lab results is instantaneous, and execution of algorithms to detect exceptional conditions is on a scheduled, periodic basis. Notification of exception and alert conditions are generally received by the PCMCIA receiver within one minute of detection. However, radio transmission is subject to data traffic or other delays within the StarLink messaging system. In many instances the clinician receiving wireless notification of critical lab results is the first individual to be aware of and to respond to a life-threatening condition, in spite of the fact that the critical lab data was simultaneously posted to the patient's electronic chart. A PDA screen reporting a lab data alert is shown in Figure 2.

Exception conditions were detected 108 times over a three month study period (1/1/95 - 3/31/95) involving 10.3% of ICU patient days (Table).

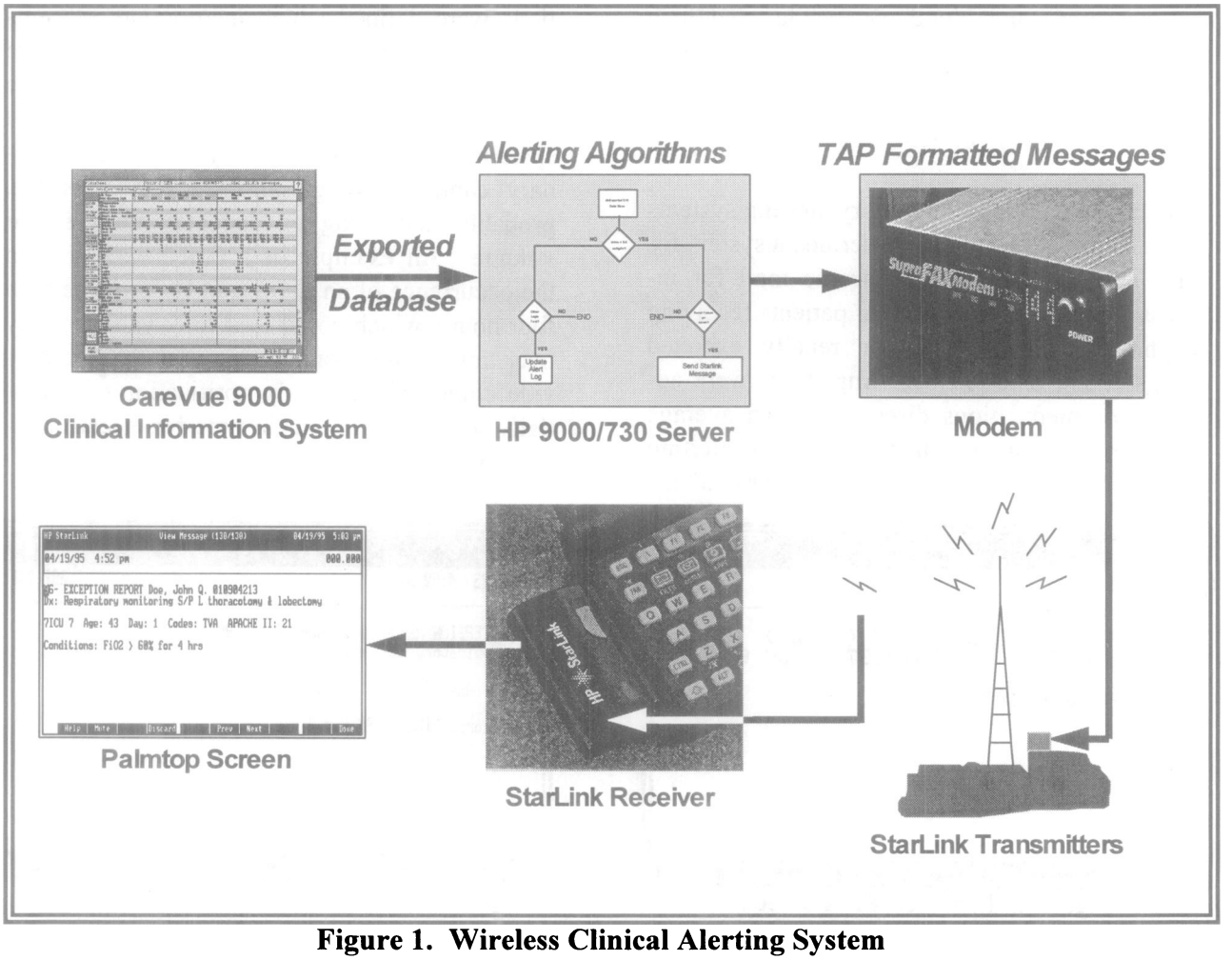

Figure 1. Wireless Clinical Alerting System

Table. Exception Conditions

Patient Days	Patients with Exceptions	Multiple Exceptions
1,052	85 (8.1%)	23 (2.2%)

A PDA screen reporting an exception condition is shown in Figure 3. During the course of this study, a life-threatening condition requiring immediate intubation and mechanical ventilation was reported through the wireless alerting system. Although the same data had been sent to a bedside workstation, the patient's nurse was attending a patient in another room and a physician in patient's room was unaware of the condition. Thus, only the physician carrying the Palmtop alerting system responded to intubate the patient. We have previously reported that critically abnormal results are present in 1.32% of laboratory and blood gas results sent to a Surgical ICU.[7] The incidence of lab alerts was not recorded in the present study.

DISCUSSION

The clinical value of laboratory alerting systems is well known. Rind et al described a system for alerting physicians via electronic mail for increases in serum creatinine in patients receiving nephrotoxic medications or renally excreted drugs.[8] He reported that drug doses were adjusted or medications discontinued an average of 21.6 hours sooner than without the alerting system. Shabot et al reported that critical lab alerts were sensitive indicators of severity of illness and were predictive of outcome.[7] Patients with one or more lab alerts suffered an ICU mortality of 9.5% and had a 6.6 day average length of ICU stay, compared to 0% ICU mortality and a 1.5 day length of stay for patients with no alerts.

Rule-based medical alerting systems have been used for many years, usually for a specialized body of knowledge, such as the MYCIN system for antibiotics.[9] As more and more clinical data is accumulated is a CIS, the ability to perform more sophisticated alerts grows. Indeed, such alerts may be more valuable for quality patient care than the underlying automated documentation.

In the present study the authors present two new methods. First, a variety of exception conditions were defined which incorporate concepts of cross-correlation of clinical data and of events which occur over time. An example of a cross-correlated exception is the combination of systolic blood pressure < 80 mmHg and pulmonary capillary wedge pressure < 10 mmHg, probably indicating inadequate intravascular volume. An example of a timed exception in the occurrence of an FiO2 > 60% for more than four hours, which could lead to oxygen toxicity over time. Exception alerts are intended to provide clinicians with early notification of potentially serious conditions in time for effective intervention, if indicated.

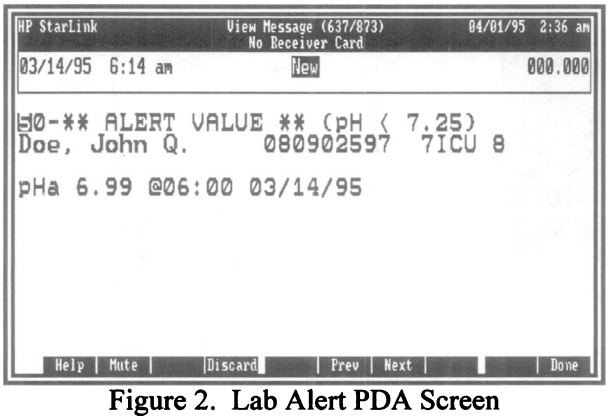

Figure 2. Lab Alert PDA Screen

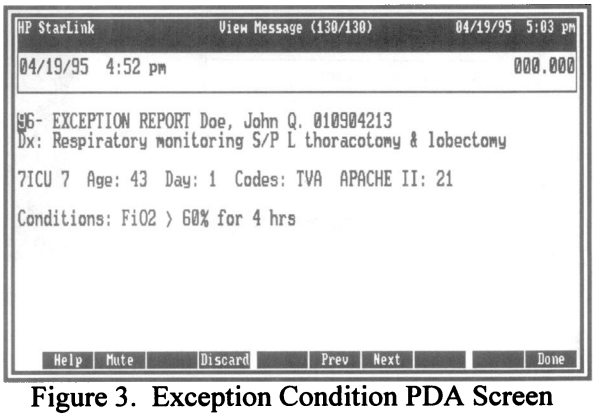

Figure 3. Exception Condition PDA Screen

Second, the authors have described a system for wireless notification of important clinical events which insures that the message is received by the responsible clinician. Previously described notification systems, including electronic mail and alert messages displayed on computer screens, require that a caregiver be at a workstation and actually read the mail or review the alert message. The new wireless system delivers the alert message directly to the clinician's pocket PDA, and heralds its arrival with a configurable series of tones and a flashing light on the PCMCIA receiver card. Further studies are required to determine if immediate wireless notification for critical and exceptional events leads to improved patient outcome.

FUTURE ENHANCEMENTS

One hindrance to the use of the system described is the availability of radio coverage for the StarLink transmission system. At certain locations or inside some buildings, incomplete messages may be received. The StarLink system does not currently provide for detection or correction of data transmission errors, but such an enhancement could be added later. In addition, the current system does not provide a way for the clinician to respond wirelessly from a remote location, although this could be done by modem or by cellular phone. It is anticipated that forthcoming Personal Communication Service (PCS) PCMCIA cards will provide for two way communication between clinicians and patient care systems.

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